Spatial Variation of Nuclear Structure Functions and Heavy Quark Production*

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We discuss the effects of spatially dependent nuclear parton distributions on charm and bottom production cross sections as a function of impact parameter. Assuming that shadowing is proportional to the local nucleon density, we study the dependence of heavy quark production on the nucleon structure functions and the shadowing parameterization.

The heavy quark production cross section changes significantly when this spatial dependence is considered. The variation with impact parameter is especially important because relatively peripheral collisions are often used as a baseline in searches for new phenomena in more central collisions. Peripheral collisions tend to probe the nuclear surface where shadowing is rather weak while central collisions are also sensitive to structure functions at the nuclear core where nuclear modifications can be large.

The nuclear parton densities $F_i^A(x,Q^2,\vec{r},z)$ can be represented as the product of x and Q^2 independent nuclear density distributions, position and A independent nucleon parton densities, and a shadowing function that contains the modification of the nuclear structure functions,

$$F_i^A(x,Q^2,s) = \rho_A(s) S^i(A,x,Q^2,s) f_i^p(x,Q^2) \ ,$$

where $f^p(x,Q^2)$ are the nucleon parton densities. In the absence of nuclear modifications of the structure functions (no shadowing), $S^i(A,x,Q^2,\vec{r},z) \equiv 1$. The nuclear density is given by a Woods-Saxon distribution.

The shadowing effect is studied with parameterizations based on nuclear deep-inelastic scattering. The first, $S_1(A,x)$ is based on fits to recent nuclear deep inelastic scattering data and treats the quark, gluon and antiquark functions equally without Q^2 evolution. The second, $S_2^i(A,x,Q^2)$ has separate modifications for the valence quarks, sea quarks and gluons and includes Q^2 evolution.

We assume that these modifications are proportional to the undisturbed local nuclear rest density,

$$S^i_{\rm WS} = 1 + N_{\rm WS}[S^i(A,x,Q^2) - 1]\frac{\rho(s)}{\rho_0} \ ,$$

where $N_{\rm WS}$ is a normalization constant chosen such that $(1/A)\int d^3s \rho(s) S^i_{\rm WS} = S^i$. At large radii, $s \gg R_A$, medium modifications weaken so that in very peripheral interactions, nucleons behave act as if they are in free space. At the center of the nucleus, the modifications are larger than the average value found in lepton scattering experiments.

Our results show that using peripheral collisions as a baseline for comparison to central collisions can lead to significant errors if the spatial dependence of shadowing is not taken into account. At RHIC and LHC, the cross section is generally higher in peripheral collisions than might be expected without any spatial dependence of shadowing. We note however that the spatial dependence of the shadowing is not evident until $b > 1.2R_A$, requiring studies of peripheral collisions to determine the strength of the effect.

In conclusion, we have shown that introducing a very natural spatial dependence in nuclear shadowing changes the heavy quark production rates in heavy ion collisions, altering the expected relationship between central and peripheral collisions. This alteration could lead to a misinterpretation of the transverse energy dependence of certain quark-gluon plasma signatures.

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